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THE EFFECT OF PURE ALUMINIUM COATING ON CORROSION RESISTANCE OF $ALCU_4MG_1$ ALLOY

VLIV POVLAKU ČISTÉHO HLINÍKU NA KOROZNÍ ODOLNOST SLITINY $ALCU_4MG_1$

Abstract

The paper deals with the corrosion research of wrought aluminium alloy ($AlCu_4Mg_1$) and comparing results with the same material coated by 99.5% aluminium. As the corrosive medium the neutral salt spray of 5% NaCl aqueous solution was used. The course of the corrosion resistance test was in accordance with the standard EN ISO 9227. The experiments were carried out with increasing exposition time of 48, 96, 240, 480, 720 and 1000 hours. The weight losses were measured and calculated in g/m^2 and mm/year. Corrosion type was assessed by comparison with etalons after the standard ČSN 03 8137, the most frequent corrosion damage was indentified corrosion pitting for both materials. The depth of corrosion attack was observed on cross-section cuts by light optical microscope and detected by image PC software Olympus Analysis 5.

Abstrakt

Příspěvek je zaměřen na zkoumání korozního chování hliníkové slitiny v prostředí neutrální solné mlhy dle platné normy EN ISO 9227. Zkoušeny byly dva typy materiálu, tj. tvářená slitina $AlCu_4Mg_1$ v základním stavu a s ochrannou vrstvou z čistého hliníku. Korozní testy byly provedeny se zvyšující se dobou expozice (48, 96, 240, 480, 720 a 1000 hodin). Naměřené hmotnostní úbytky byly přepočítány na g/m^2 a korozní rychlost v mm/rok. Porovnáním s etalonem dle normy ČSN 03 8137 byla pro oba materiály jako nejčastěji se vyskytující typ vyhodnocena důlková koroze. Hloubka korozního napadení byla zkoumána na příčných metalografických řezech na světelném mikroskopu a vyhodnocena na základě výsledků obrazové analýzy s využitím PC softwaru Olympus Analysis 5.

1 INTRODUCTION

Al and Al alloys are attractive in many technological applications due to its characteristics such as light weight, durability and good corrosion resistance [1]. Frequent uses of these materials are in the automotive and aerospace industry [2]. The resistance of aluminium against corrosion in aqueous media can be attributed to a rapidly formed surface oxide film, which is composed of Al_2O_3, $Al(OH)_3$ and AlO(OH) phases. Nevertheless, the presence of aggressive ions like chlorides causes

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significant attack [3, 4]. The main corrosion process that is developed on the surface of aluminium alloys in a NaCl solution is the localized alkaline corrosion in the aluminium matrix surrounding Al(Mn, Fe, Cr) cathodic intermetallics [5].

The main aim of this study is comparison of corrosion resistance of AlCu4Mg1 alloy with and without protective coating in neutral salt spray environment.

2 EXPERIMENTAL MATERIAL

The AlCu4Mg1 wrought aluminium alloy with 99.5% Al coating and the same alloy with any surface coating were used in the present study. The first material was received as a sheet with dimensions of 100 x 150 x 1 mm. Fig. 1a) shows original microstructure of this material. The thickness of Aluminium coating measured by image software was 40 μm. The second material (i.e. without coating) was received as a L-beam with dimensions 14 x 14 mm with length 150 mm and thickness 2 mm and its microstructure shows Fig. 1b).

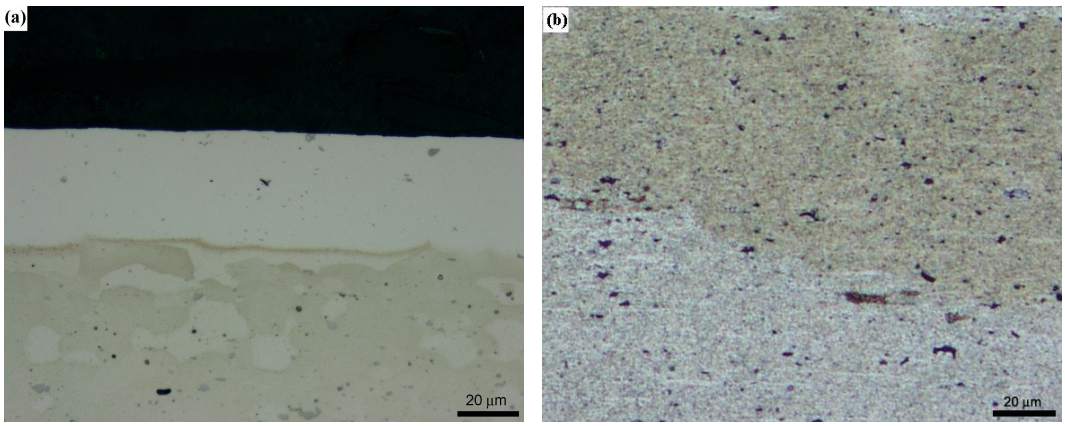

Fig. 1 The microstructure of experimental materials (a) AlCu4Mg1with protective Al coating and (b) AlCu4Mg1, light microscopy

The grains and surface coating were revealed by etching using a FUSS solution (7.5 ml HF, 8 ml HNO_3, 25 ml HCl and 1000 ml H_2O). The chemical composition of both materials was measured by glow discharge optical emission spectroscopy (GDOES) using Spectrumat GDS-750 device. These data were measured on the surface and below protective coating for sheet and together with chemical composition of L-beam are given in Tab. 1. [6].

Tab. 1 The chemical composition of experimental materials measured by GDOES

	Si	Fe	Cu	Mn	Mg	Cr	Zn	Ti	Sn
Surface of sheet	0.12	0.20	0.01	0.00	0.01	0.00	0.02	0.02	0.01
Sheet	0.19	0.21	4.40	0.44	1.69	0.01	0.03	0.04	0.01
L-beam	0.21	0.31	4.10	1.08	1.71	0.00	0.03	0.02	0.00

3 EXPERIMENTAL PROCEDURE

For the assessment of the corrosion behaviour of the specimens of an aluminium alloy in a spray of neutral aqueous solution of sodium chloride the corrosion chamber Angelantoni DCTC 600 P was used. The course of the corrosion resistance test was in accordance with the standard EN ISO 9227 [7]. The experiments were carried out with increasing exposition time of 48, 96, 240, 480, 720 and 1000 hours. Every cycle was conducted in the test environment of 5 % aqueous solution of NaCl with pH = 6.9 and temperature 35 °C ± 2 °C.

Final cleaning of the specimens after exposition was carried out by dipping in a solution of CrO_3 + H_3PO_4 + H_2O; according to Czech standard ČSN 03 8452 [8]. The weight loss was measured at analytical balances (d = 0.1 mg) after each experiment and calculated in g/m^2 and mm/year.

4 RESULTS

Measured weight losses and calculated corrosion rate of experimental materials as a function of time exposure are presented in Fig. 2. The depths of corrosion attack were detected by PC software Olympus Analysis 5 on the cross-sectioned cuts. The average depth dependence on time of exposure shows Fig. 3 and the maximum depth versus time of exposure shows Fig. 4.

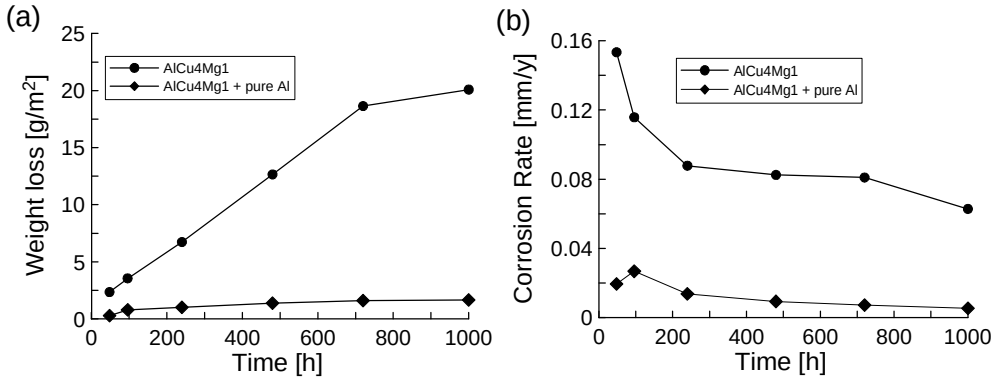

Fig. 2 The comparison of (a) weight losses and (b) corrosion rate of experimental materials as a function of exposure time in corrosion chamber

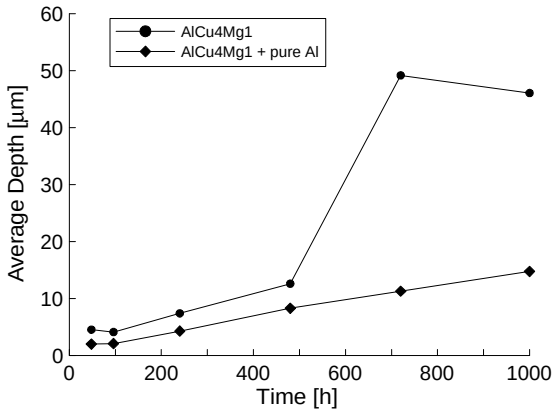

Fig. 3 The graphical dependence of the average depth of attack on the time of exposition

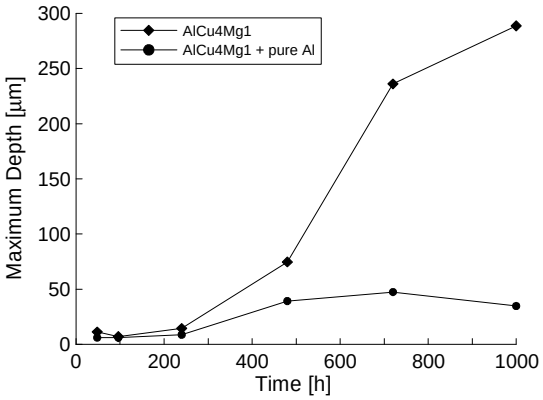

Fig. 4 The graphical dependence of the maximum depth of attack on the time of exposition

Metallographic evaluation was performed according to applicable standard ČSN 03 8137 [8]. The corrosion attack after representative time of exposition observed by light microscope on metallographic cross-section cuts is shown in Fig. 5. Surface profiles of specimens with protective Al coating after exposure time 96, 480 and 1000 hours are presented in Fig. 5 a), c) and e), respectively. Fig. 5 b), d) and f) shows surface profiles of samples AlCu4Mg1 alloy after exposure time 96, 480 and 1000 hours, respectively.

5 DISCUSSION

Corrosion resistance of the wrought aluminium alloy AlCu4Mg1 with and without protective Al coating were studied. The samples shaped as a sheet and L-beam were used for testing in neutral salt spray test. The thickness of pure Aluminium coating detected by image software was 40 μm before exposition.

Fig. 2 shows weight losses and corrosion rate as a function of exposure time. It is clear that weight losses of alloy without pure Al are significantly higher and increasing with longer times. The dependence of corrosion rate on exposure time shows the greatest drop between 96 and 240 hours for both materials. Further progress was only slightly decreasing.

Metallographic evaluation was carried out on cross-section cuts. Fig. 5 shows the comparison of corrosion attack of experimental materials. Pitting was observed after every exposure time for both materials with different average depth. The dependence of the average depth of corrosion attack on exposure time is presented in Fig. 3. The average depth of the pits is the rate of corrosion attack but does not catch the absolute depth because on the metallographic cuts are shown the edges of pits in an indefinite depth. Maximum depth versus time of exposure (see Fig. 4) better reflects the severity of corrosion attack. Substantially more intensive progress was observed in case of L-beams. The L-beams also exhibited some differences in the depth of corrosion attack on the edges compared to that on the planes. Only small discrete areas of corrosion damage were found on the both types of specimens at shorter times of exposure. Pitting deeper than thickness of Al coating occurred rarely already after 240 hours of exposition time (see Fig. 5c). On the samples with protective coating after exposition 1000 hours the places attacked by uniform corrosion were clearly visible (see Fig. 5e). However, this appearance can be caused by lateral joining of multiple pitting defects. Thickness of the coating on these samples was determined as 28.30 μm (+/- 6 μm). After the time of exposure of 480 h and longer the intergranular corrosion started to occur besides the corrosion pitting. The intergranular corrosion (see Fig. 5f) progressed along the grain boundaries and was observed mainly below the specimen´s surface, starting from the edges of specimens. The origin of the intergranular corrosion can be explained in conjunction with the occurrence of intermetallic phases, which were found to contain large amounts of aluminium, copper and magnesium, and its mechanism should be identified as the electrochemical corrosion. This type of corrosion has the prerequisite in the existence of electrochemical microcell that is created between the matrix and the Al_2CuMg phase, which exhibits ca-

thodic behaviour in NaCl solution. Thus created microcell accelerates the corrosion process markedly, especially in its initial stage.

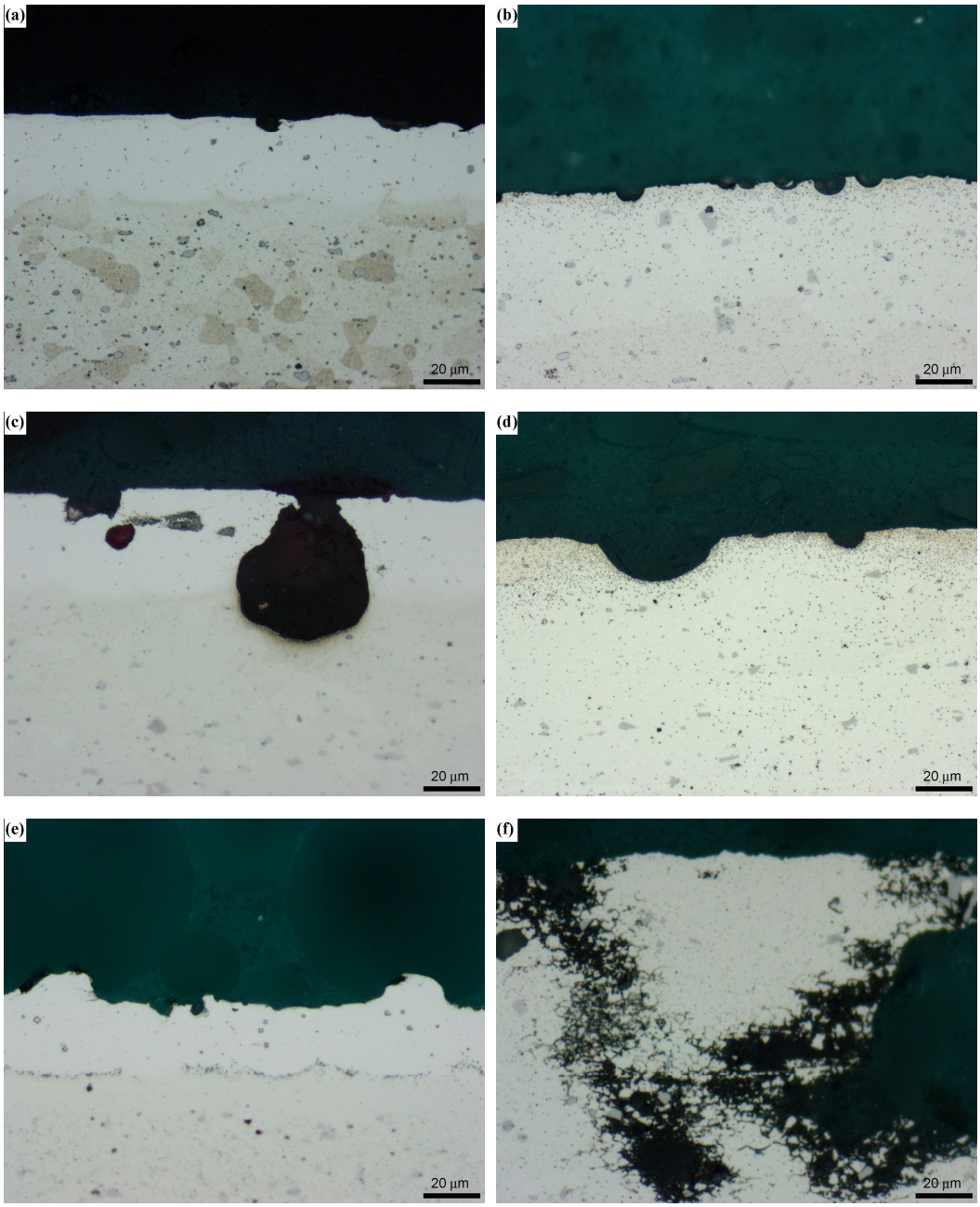

Fig. 5 Surface profiles of specimens observation by light microscope (a), (c) and (e) AlCu4Mg1with protective Al coating after exposure 96, 480 and 1000 hours and (b), (d) and (f) AlCu4Mg1 after exposure 96, 480 and 1000 hours, respectively

6 CONLUSIONS

The AlCu4Mg1 aluminium alloy with and without 99.5% Al coating was used for neutral salt spray tests in 5% NaCl aqueous solution with neutral pH.

- The corrosion type in case of sheets (i.e. with Al coating) is non-uniform, spreading over the whole surface during the time. In addition, the localized corrosion was observed. Its depth extended into the base material - AlCu4Mg1 sheet - after exposures longer than 240 hours. In case of L-beams (i.e. without Al coating) the pitting corrosion took place here, with the process advancing into depth faster than in the case of sheets. The diameter of the pits also became larger during the time.
- The L-beams material after 480 h exposure to salt fog started to exhibit the intergranular corrosion besides the pitting one. The main cause of its occurrence was the evolution of corrosion microcells between the matrix and the Al_2CuMg phase which has a cathodic behaviour in the particular environment.
- The material of the sheets with the surface protective coating of aluminium exhibited substantially higher corrosion resistance in salt fog environment.

Acknowledgements

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